UAV-Enabled Measurement on Magnetic Field of Smart Rocks for Bridge Scour Monitoring

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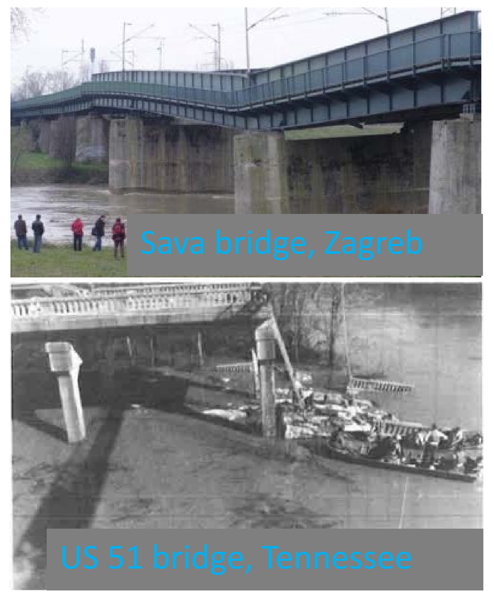
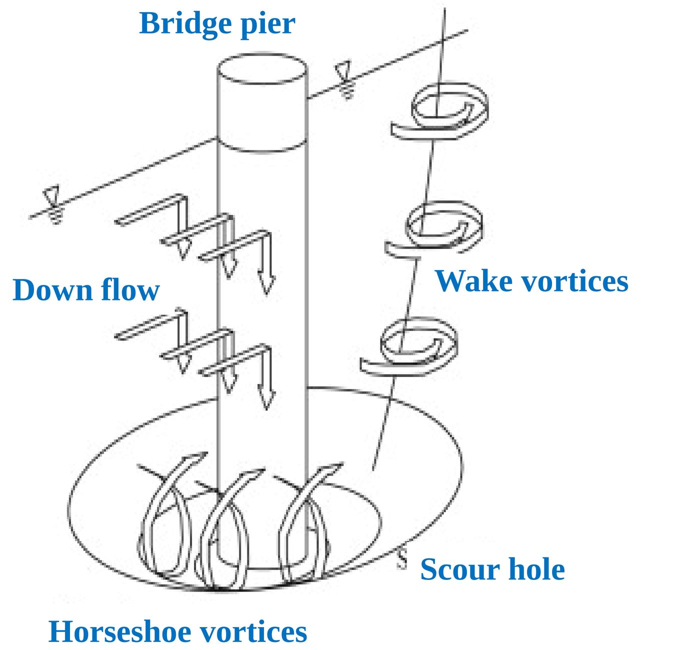
INTRODUCTION

Scour and other hydraulic induced failures accounted for 58% of over 1,500 bridge collapses in the U.S. Bridge scour is the engineering term for the erosion of soil surrounding a bridge foundation as a result of water current. Monitoring with fixed and/or portable instrumentations is one of the most effective measures in mitigating scour hazards. However, fixed instrumentation with sensors installed prior to flood events cannot detect scour other than the area instrumented. It is susceptible to the harsh environment during a flood event. Portable instrumentation is difficult to deploy during a severe flood event due to safety consideration and/or water conditions.



Typical bridge scour accidents



Scour mechanism around a bridge pier

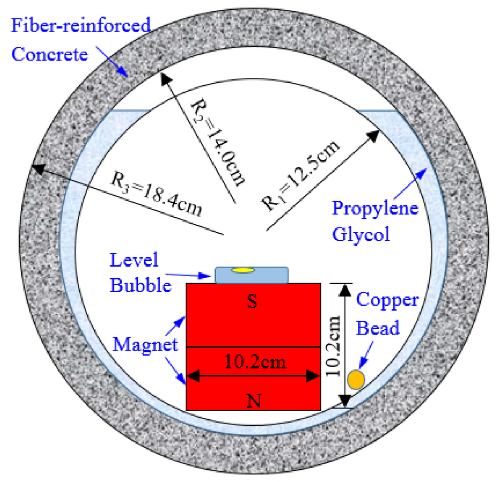
OBJECTIVES

This research aims to:

- Develop and validate a remote sensing technology with smart rocks for real-time monitoring of scour during a flood event.
- Develop a unmanned aerial vehicle (UAV) based measurement of magnetic field for localization of smart rocks.

METHODS

Smart rocks with embedded magnets are designed to automatically roll down the bottom of surrounding scour hole under strong current. Through remote sensing with a magnetometer and GPS installed on a UAV, they can relate the maximum scour depth to the engineer in charge. The magnetometer that measures magnetic fields surrounding smart rocks can be positioned by GPS. The smart rocks are localized by minimizing the difference between theoretic prediction and field measurement. The difference in two measurements over time thus represents the movement of the smart rocks during that time period.



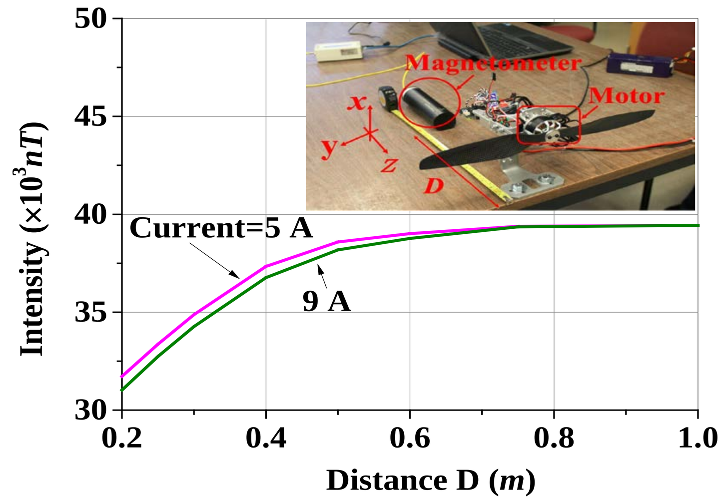
Schematic view

Inner structure

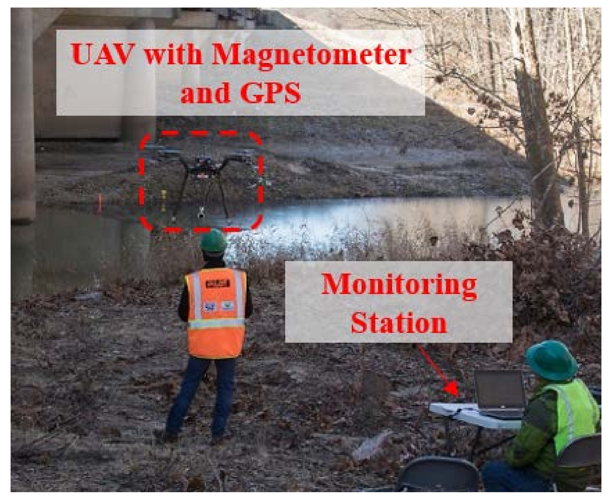
Deployment of smart rock

RESULTS

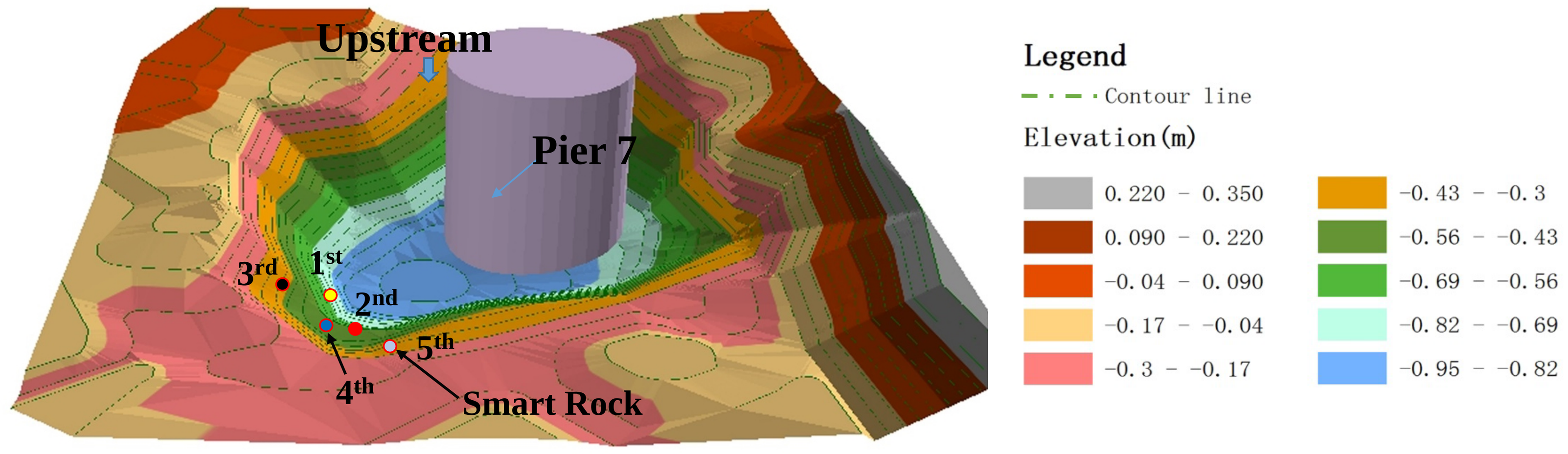
One smart rock was deployed around Pier 7 of the Roubidoux Creek Bridge, Waynesville, MO. The bridge scour depth was successfully determined using a UAV-based measurement method with an acceptable error of less than 0.5 m. The proposed UAV-based method is comparable with the conventional 'crane' method.



Motor effect on magnetic field measurement



UAV-based measurement



Movement and position of a smart rock over time

Comparison between the 'crane' and UAV-based monitoring method

Monitoring Method	Test Date	Predicted Coordinate			Measured Coordinate			Error (m)
		X_m	Y_m	Z_m	X_m	Y_m	Z_m	
Crane (1st)	11/06/2015	0.06	23.49	-3.03	0.09	23.24	-3.04	0.26
Crane (2nd)	04/14/2016	0.55	24.38	-3.21	0.37	24.60	-3.38	0.33
Crane (3rd)	10/20/2016	0.00	22.73	-2.59	0.00	22.63	-2.87	0.30
UAV (4th)	01/24/2018	0.02	23.50	-2.89	0.25	23.77	-2.93	0.36
UAV (5th)	05/10/2018	0.49	25.00	-2.81	0.45	24.78	-3.01	0.30

CONCLUDING REMARKS

A bridge scour monitoring system of a smart rock and a UAV with a magnetometer and GPS was proposed. It was tested at a bridge site and compared with the conventional 'crane'-supported measurement. The following conclusions can be drawn.

- The smart rock deployed at the Roubidoux Creek Bridge was located successfully and satisfactorily. Its movement during five field tests were successfully determine by using the traditional 'crane' and the proposed UAV enabled monitoring method, both introducing a monitoring error of less than 0.5 m. The Smart Rock moved down the scour hole by 0.18 m during the Dec. 27, 2015, event.
- The UAV-based monitoring method leads to comparable results to those of the conventional 'crane' monitoring method. It can rapidly collect a dense array of magnetic field intensity data at a bridge site. The large data set is helpful to improve the accuracy of smart rock localization and movement prediction.
- Future study will be directed to understand and quantify the potential interference of two or more smart rocks in magnetic field measurement and rock positioning algorithm.

REFERENCE

G.D. Chen, Y. Tang, Y.Z. Chen, Z.C. Li, C.R. Guo, L. Fan, Y. Bao, X.Y. Hu, and M. Klegseth. "Smart Rock Technology for Real-time Monitoring of Bridge Scour and Riprap Effectiveness – Design Guidelines and Visualization Tools", Final Report submitted to USDOT/OST-R, December 31, 2016.

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